A STUDY OF THE HUMAN FLESH SEARCH ENGINE: CROWD-POWERED EXPANSION OF ONLINE KNOWLEDGE

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This first comprehensive empirical study of a search function that originated in China examines its tremendous growth in recent years and its uniquely rich online/offline interactions.

The concept of *human flesh search* (HFS) originated in China where it has become an explosive Web phenomenon in the past five years. In China, Web users routinely employ HFS to identify corrupt government officials and individuals engaged in other illegal or unethical activities. HFS has also played a positive role; providing public services such as helping people find missing relatives during crises. Increasingly, companies and celebrity hopefuls have also started to exploit HFS as an advertising and public relations platform.

So, what is human flesh search? The term derives from a literal translation of its original Chinese root 人肉搜索, which refers to searches that are conducted with help from human users (as opposed to on a purely automated platform, such as Google), often targeted at finding the identity of a human being. A more accurate translation would be "people-powered" search. A precise definition in a computational context is still forthcoming since, as a real-world Web phenomenon, HFS is still evolving. Many erroneous notions have appeared on various blogs, on wiki sites, and in media reporting, but because they come from non-Chinese sources, they tend to be narrow and often overly specific. For example, a blog entry on SearchEngineWatch.com defines HFS as "finding and punishing people who publish material Web users consider inappropriate" (http://blog.searchenginewatch.com/080627-115435). A June 2008 *Times Online* article (http://technology.timesonline.co.uk/tol/news/tech_and_web/article4213681.ece) characterizes HFS activities as "digital witch hunts." Finally, a guardian.co.uk blog entry (www.guardian.co.uk/commentisfree/2008/nov/02/chinathemedia-blogging) refers to HFS as "an internet mob that hunts down real people online, then verbally abuses them and publishes the victim's private information."

Chinese-based sources offer broader definitions. For example, ChinaSupertrends.com defines HFS as "online crowds gathering via China's bulletin board systems, chat rooms, and instant messaging to collaborate on a common task" (www.chinasupertrends.com/chinas-human-flesh-search-engine-not-what-you-might-think-it-is).

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To study HFS empirically, we've collected a comprehensive set of online episodes commonly labeled as HFS events, from their inception in 2001 to 5 May 2010. Our data collection strategy involved both automatic Web crawling and manual search. Sources covered included media reports (both online and printed), online forums, blogs, video sharing sites, game chat rooms, and results from general Web searches, among others. Our dataset contains 404 HFS episodes. For all of these episodes, we have episode-level information covering items such as the start and end times of HFS activities, the major types of online and offline activities that have taken place (often reconstructed from secondhand material such as media reporting), the nature of the event, and the final outcome of HFS. For 211 of these episodes, we were able to collect raw postings and discussion threads from 783 URLs on 103 distinct websites. The total number of postings in our dataset exceeds 1.1 million.

Based on our data, two defining characteristics of HFS stand out. First, most HFS episodes involve strong offline elements, in the form of either information acquisition through offline channels or other types of offline activism. Second, almost all HFS events rely on voluntary crowdsourcing: a team of Web users join each other to share information, conduct investigations, and perform other actions concerning people or events of common interest.

From a systems standpoint, HFS engines (HFSEs) are platforms—dedicated websites and online forums—that enable HFS activities by broadcasting requests and action plans, sharing online and offline search results, and sometimes, although rarely, offering specific rewards. In our analysis, information from offline sources refers to information accessible (either readily available or acquired through some effort) to some HFS participants but not yet available from any online sources. Offline actions or activities are those taken in the physical world and outside the Web environment.

EMPIRICAL ANALYSIS

We can trace back the first HFS episode to 2001, when a user posted a photo of a young woman on a Chinese online forum, part of Mop.com, an interactive entertainment website, and claimed she was his girlfriend. A number of users then performed a range of online and offline searches, seeking to reveal her identity. Finally, one of them positively identified the young woman (who happened to be a minor celebrity) and posted her personal relationship information online, discrediting the claim made by the user who initially posted the photo.

One of the most famous and possibly biggest episodes as measured by number of participants involved HFS and the "South China Tiger" event. In 2007, a hunter in Shaanxi Province, China, claimed to have encountered a live wild South China Tiger, which, as a species, has long been considered extinct in natural environments. This hunter photographed the tiger, and the image subsequently appeared in an issue of *Science* magazine ("Rare-Tiger Photo Flap Makes Fur Fly in China," www.sciencemag.org/content/vol318/issue5852/r-samples.dtl).

After these photographs were published in various outlets and posted online, Web users around the world sought to prove or disprove their authenticity, leveraging domain expertise that ranged from zoology, botany, and photography to geometry. Finally, an HFS participant successfully identified the original calendar cover painting from which the hunter had copied the photograph to create and edit the claimed South China Tiger pictures. Consequently, the HFS process ended with proof that the South China Tiger photos and claims were indeed scams.

Another HFS episode, the "outrageously priced haircut" episode, offers an alternative case of a much more local nature, in Zhengzhou City, Henan Province, China, in 2008. Two students were forced to pay an extraordinary amount of money (200 times the advertised price) for a regular haircut in a local barbershop. The staff working at the barbershop claimed that they had "deep connections" (presumably with the local government and the police) and they were not afraid of any media investigation. The local people were enraged and started HFS to identify who these claimed "deep connections" were. A local group was formed to conduct physical investigations in offline settings as well. In addition, net citizens demonstrated in front of this barbershop and vandalized it. The government investigated the case and fined the barber owner a half million RMB (Chinese Yuan, about $74,000) for illegal pricing schemes.

In recent years, HFS has become an international Web phenomenon. From 2001 to the end of 2007, about 35 HFS episodes occurred, with 31 taking place in China (including the Chinese mainland and Taiwan), one in Japan, one in Korea, and two in the US. In 2008, a total of 114 HFS episodes took place, with 111 occurring in China, one in the UK, one in France, and one in the US. In 2009 a total of 168 HFS episodes were reported, with two in the US, one in Japan, one in Korea, one in Lithuania, and the rest in China. From January 2010 to the beginning of May 2010 there were 87 HFS episodes, with one in the US, one in the UK, and the rest in China. From the beginning of 2008 forward, the frequency of HFS episodes has risen drastically, an upward trend that continued throughout 2009 and 2010. Figure 1 plots the number of HFS episodes quarterly over time. The peak in 2008 is attributed to activities related to the Beijing Olympics and Sichuan earthquake. Figure 2 plots the ratio of the number of HFS episodes quarterly over the number of Internet users in China. Clearly, the increase in HFS activities isn't simply due to a growth in Chinese Internet use.

HFS episodes typically start with the formation of a small seed community issuing a task with a defined goal. For more than half of HFS episodes, information about the context

and underlying event appeared first on an online forum, which in most cases became the portal of ensuing HFS-related activities for this particular episode.

For the others, "trigger" stories from sources such as TV and online news, websites such as tudou.com, or print-based newspapers appeared first on an online forum. Members then started discussions about these stories, which in turn initiated HFS activities. Less than 5 percent of these HFS events started with a cash reward, differentiating HFS from Amazon's "Mechanical Turk" (www.mturk.com) and other sites where people participate primarily for monetary gain. We also note that in almost all episodes, the participants include large numbers of people with no particular identifiable skill base, differentiating this from open source development activities and other skill-based Web communities.

As HFS activities move into full swing, participants typically engage in a wide range of online and offline activities. In about 50 percent of HFS episodes, Web users reported their offline findings back to the online discussion; in about 30 percent of them, traditional media or Web media were involved.

Offline, some HFS participants offered donations or other activities to help victims. In some cases, enraged Web users made phone calls or even harassed the suspected culprit and associated family members. In October 2008, one HFS episode resulted in the tragic death of an innocent victim (http://news.sina.com.cn/s/2009-04-17/100817629779.shtml). The girlfriend of a young man broke up with him and moved to a different city. In an attempt to locate her, this young man started an HFS by claiming that he was dying and wanted to see his exgirlfriend one last time. Out of sympathy to this "dying" man and his last wish, the HFS community mobilized and successfully found the girl's location. The young man went to meet with her, and after an unsuccessful bid to win her back, killed her with a knife. After this tragic and senseless event, along with several other less-serious incidents that involved violations of privacy that led to harassment, insults, and job-related firings, the HFS community engaged in a postsearch retrospective analysis to determine if the HFS requestors or originators had a hidden purpose. The community examined both the legality and negative social impact of HFS activities.

Figure 3 shows the information and control flow between online communities and the offline environment.

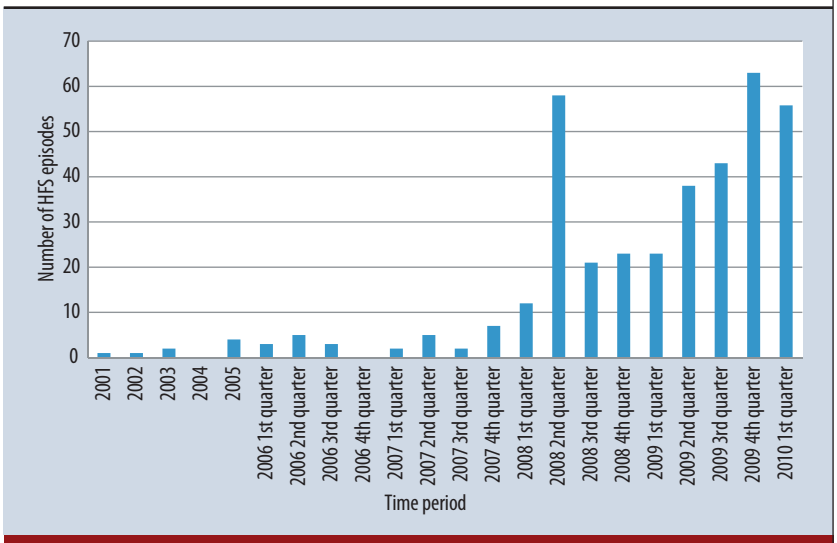

Figure 1. Evolution of human flesh search episodes quarterly, over time.

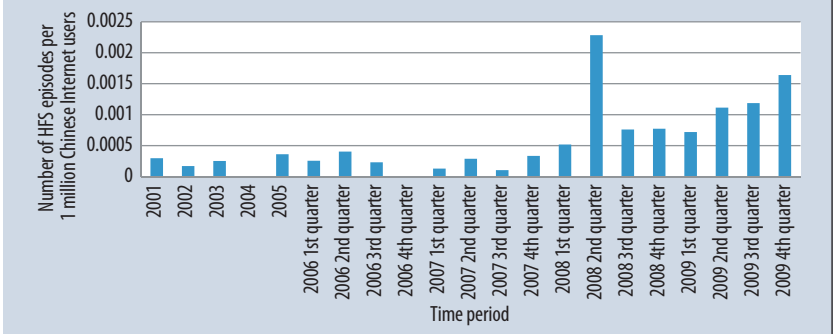

Figure 2. Quarterly ratio for the number of HFS episodes over the number of Internet users in China.

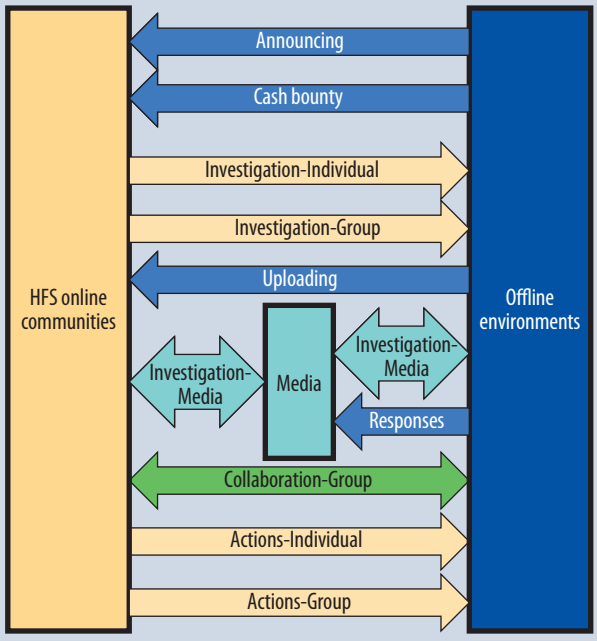

Figure 3. Information and control flow for HFS online/offline interactions.

Table 1. Types of online/offline interactions in HFS.

Type of interaction	Description
Announcing	Announcing on a blog/online forum event information acquired offline to trigger HFS
Cash-bounty	Offering cash bounty for information
Uploading	Sharing/uploading information identified offline by HFS contributors in response to discussion threads
Responses	Responses from subjects (individual or organizations) impacted by HFS as a consequence of discussion threads and related media coverage
Investigation (individual)	Offline investigation by individual HFS contributors
Investigation (media)	Offline investigation by reporters from traditional media
Investigation (group)	Offline investigation by groups of HFS contributors organized through various HFS channels (online forums, instant messaging)
Actions (individual)	Offline actions/responses (demonstrations, phone calls, donations) by individual task contributors
Actions (group)	Offline actions/responses by groups of HFS contributors organized through various HFS channels
Collaboration (group)	Offline collaboration between groups of HFS contributors and real-world organizations

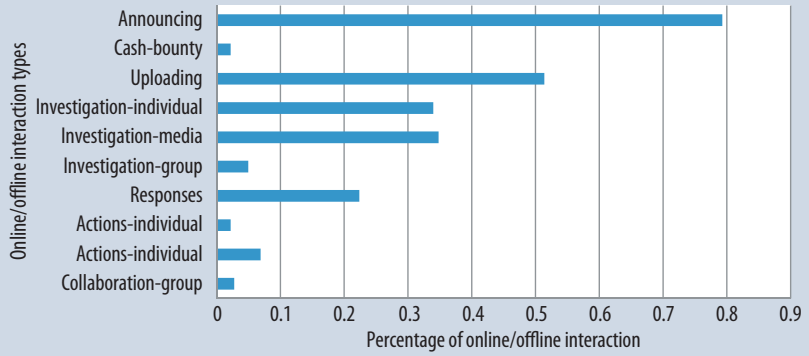

Figure 4. Prevalence of various online and offline interaction types occurring during HFS interactions.

Table 1 summarizes the various types of online/offline interactions that manifested in these HFS episodes. Figure 4 shows the prevalence of various online and offline interaction types that occurred during the HFS interactions.

NETWORK ANALYSIS OF HFS COMMUNITIES

The research opportunities HFS offers to social and computational scientists are boundless and include social network analysis as well. The case studies we describe in this section analyze two different networks of HFS participants and seek to shed light on two research questions. First, how do HFS participants interact? Second, how do HFS online communities differ from other online communities?

Our HFS dataset consists of a large set of HFS episodes occurring between 2001 and May 2010. For each episode, we employed automatic Web crawling methods to extract information about participants and the connections among them. The two case studies are based on two episodes from this dataset, selected to represent two very different networks—national episodes and local episodes. National episodes refer to events with national or global impact that have

Table 2. Discussion threads analyzed for the "South China Tiger" event.

Discussion threads	Start time	Milestones
163 News comments #1	2007-10-12 17:42	The photo of the claimed tiger was publicized (Figure 6a)
XITEK Discussion #2	2007-10-13 07:30	Doubts were cast upon the photo (Figure 6b)
SINA News comments #1	2007-10-13 10:40	
TIANYA Discussion	2007-10-15 18:11	
SINA News comments #2	2007-10-24 02:25	Official investigation commenced (Figure 6c)
MOP Discussion #1	2007-10-31 03:41	
MOP Discussion #2	2007-11-01 14:51	
MOP Discussion #3	2007-11-03 04:51	
163 News comments #2	2007-11-14 02:19	Another investigation started
XITEK Discussion #2	2007-11-16 10:30	The original image from a calendar cover painting was found (Figure 6d)
SINA News comments #3	2007-11-16 14:43	The original calendar cover was publicized; HFS ended

attracted people from all over the country to participate. Local episodes refer to events that mainly took place locally and engaged a local, typically small, Internet user community. About one-fourth of the episodes are classified as national episodes and the rest as local episodes.

In the following, we present the network analysis of the two most typical national and local episodes. In our analysis, each node in a participant network corresponds to a unique user ID, typically associated with one distinct HFS participant. The existence of an edge between two nodes indicates the presence of Web posting citations between these two corresponding participants.

Case study I: 'South China Tiger' network

The "South China Tiger" episode involved many HFS engines, but five (tianya.cn, xitek.com, mop.com, 163.com, and sina.com.cn) played a critical role. For the purpose of constructing the South China Tiger participant network, we manually identified 11 of the most important discussion threads from these five HFS engines: one from tianya.cn, two from xitek.com, three from mop.com, two from 163.com, and three from sina.com.cn; Table 2 shows a summary. In total, this network consisted of 5,612 distinct nodes and 7,930 distinct edges. Figure 5 shows the entire network, with all discussion threads included, and Figure 6

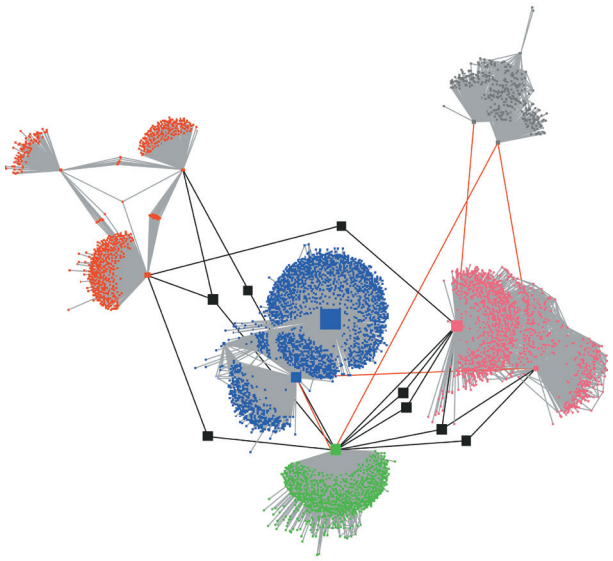

Figure 5. South China Tiger HFS participant network. The nodes are represented by colors: tianya.cn is green, xitek.com is pink, mop.com is red, 163.com is blue, sina.com.cn is dark gray, and cross-platform nodes are black. For edge colors, intra-HFS engine links are gray; inter-HFS engine links are black; and virtual links are red, denoting information flow that didn't appear with URLs or user IDs; the size of nodes represents the in-degree (with the exception of the across-platform nodes, which are highlighted with a larger size).

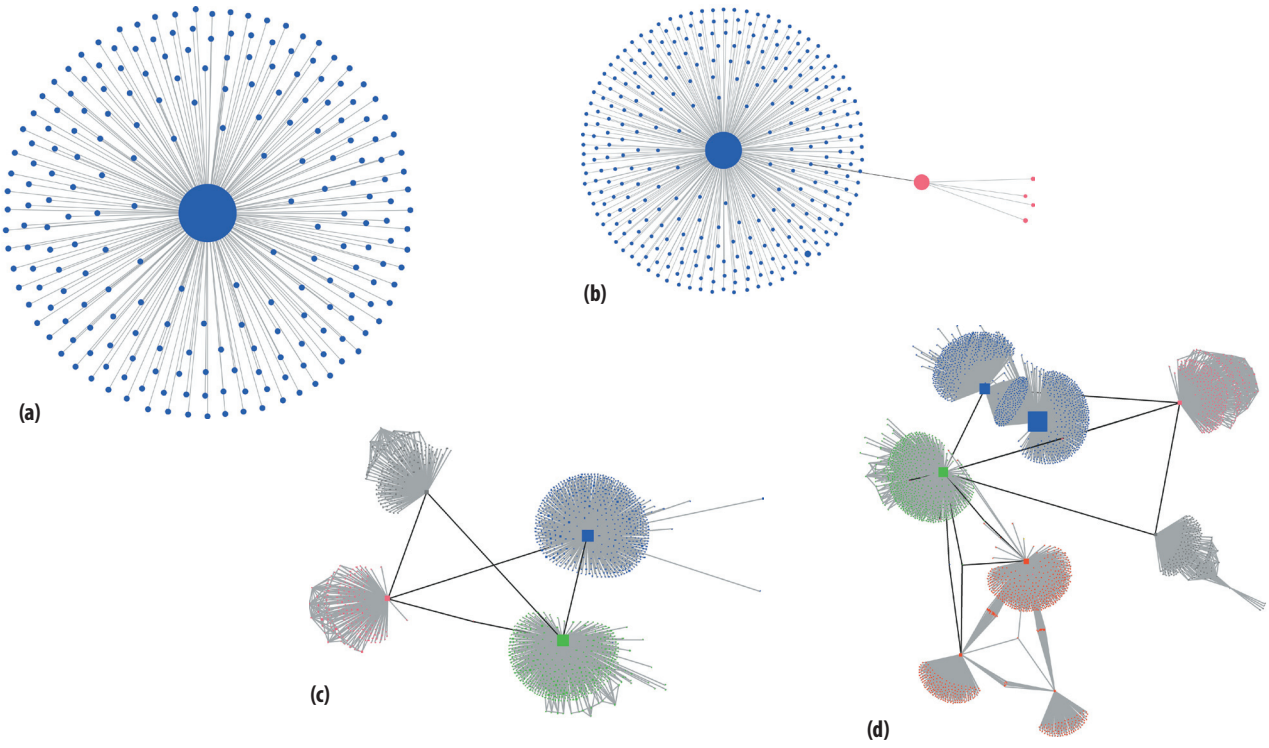

Figure 6. Growth of the South China Tiger HFS network. (a) Only one thread appeared at first, and then (b) the HFS spread to the professional photography forum xitek.com. (c) The official investigation started and then (d) ended with discovery of the original poster.

Table 3. Discussion threads analyzed for the "outrageously priced haircut" event.

Discussion threads	Start time	Milestones
Dahe discussion #1	2008-4-1 17:42	The news was publicized; "call for HFS" posted; and local Internet users started to conduct offline searches (Figure 8a)
Dahe discussion #2	2008-4-2 23:15	Many HFS offline findings collected
Tianya discussion #1	2008-4-3 11:28	Event reported on a national forum (tianya.cn) (Figure 8b)
Dahe discussion #3	2008-4-3 11:24	Dahe users organized an offline demonstration that occured at 18:30 (Figure 8c)
Dahe discussion #4	2008-4-4 18:27	Users reported online about offline actions (the barbershop was under siege) one hour ago
Dahe discussion #5	2008-4-5 16:14	The local government fined the barbershop owner (Figure 8d)

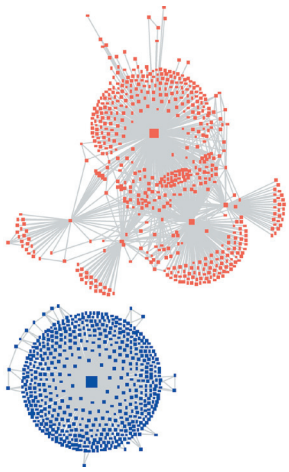

Figure 7. The outrageously priced haircut HFS participant network, with the dahe.com site in red and the tianya.cn site in blue.

shows how this network evolved across various milestones. We used the Cytoscape toolkit (http://www.cytoscape.org) for network visualization.

Case study II: 'Outrageously priced haircut' network

The "outrageously priced haircut" episode's participants lived in Zhengzhou city, and the main HFS engine focused on the local online forums hosted on dahe.com, along with another national HFS engine, tianya.cn, which played a lesser role. Table 3 summarizes the major discussion threads and event milestones.

In total, this network had 1,157 distinct nodes and 1,547 distinct edges. Figure 7 shows the participant networks on dahe.com and tianya.cn. The local discussions on dahe.com were much denser than those on tianya.cn. This is because dahe.com users were mostly local residents of

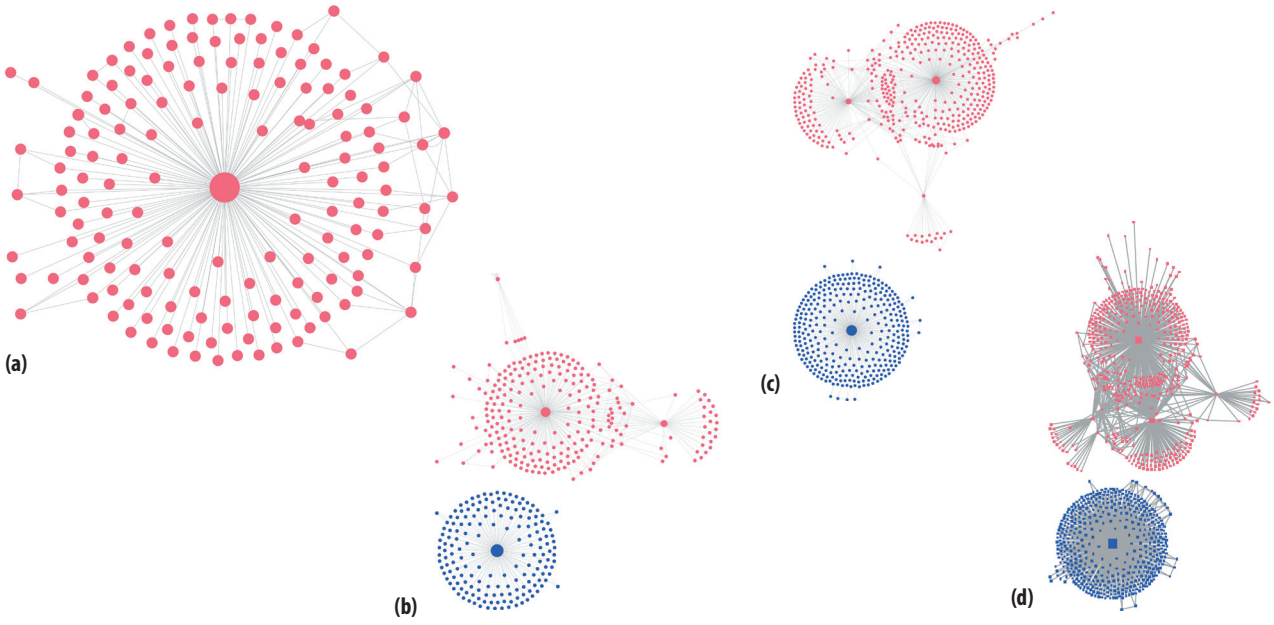

Figure 8. Growth of the outrageously priced haircut HFS network. (a) Only one thread appeared at first, and then (b) the HFS was reported on a national forum (tianya.cn). (c) The offline group investigation and demonstration started and then (d) ended with the punishment against the barbershop made by local government.

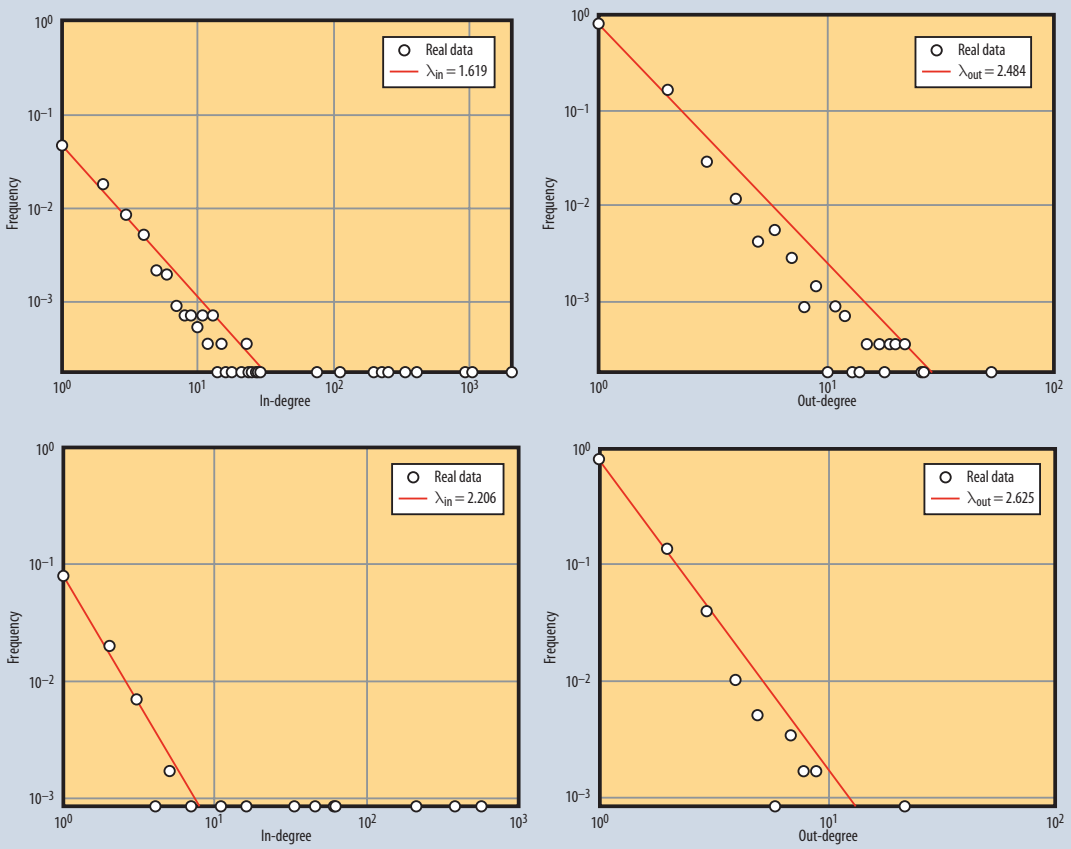

Figure 9. In- and out-degree distributions and the power-law correlation of the South China Tiger network and outrageously priced haircut network.

Zhengzhou and its surrounding areas, and they collaborated both online and offline intensely during this episode. Figure 8 shows how this network evolved across various milestones.

NETWORK PROPERTIES OF HFS COMMUNITIES

HFS communities are generally sparse, with a network density of less than 0.001. This stems from the large number of participants who post only simple, uninformative replies to existing postings. Such users typically don't contribute constructive findings or substantive information and don't attract follow-up discussions or postings. We refer to these people as *casuals*. HFS participant networks are typically highly connected. In the case of the South China Tiger network, for example, 5,612 nodes formed a giant connected component.

HFS communities usually grow quickly at the beginning of an episode. Every time a major finding is reported or milestone reached, a spike of new participants joins in and then quickly evaporates. In many HFS episodes, multiple engines with their own discussion threads were actively engaged, but few participants appeared on more than one discussion forum. Although small in number, these nodes played a pivotal role in transferring and sharing information across discussion forums and often across HFS engines.

We also observed marked differences between HFS engines. For example, in the South China Tiger network, xitek.com communities tended to be much denser than those from tianya.cn and mop.com, indicating a higher level of sharing and more intense discussion. This observation can be partially explained by noting that xitek.com is a forum for photographers and generally attracts professionals with specific types of expertise, whereas tianya.cn and mop.com appeal to general Web users who do not alwasys have expertise in photography.

Degree distribution

Degree distribution is a widely used metric to describe node connectivity in large, complex networks.[1] The degree distributions of HFS participant networks can be greatly affected by the existence of a large number of casual participants and huge hubs due to its forum-discussion nature.

As shown in Figure 9, these out-degree distributions seem to follow a power-law distribution, whereas

Table 4. Connectivity comparison among HFS, Web graph, and blogosphere samples.

Network	# of nodes	Weakly connected components (max)	Strongly connected components (max)	Fraction of SCCs in WCCs
HFS-South China Tiger	5,612	5,612 (100%)	242 (4.31%)	4.31%
HFS-outrageously priced haircut	1,157	586 (50.65%)	35 (3.03%)	5.97%
Web[4,8]	203,549,046	186,771,290 (91.76%)	56,463,993 (27.74%)	30.23%
Blog (source from BlogPulse)[4]	143,736	107,916 (75.08%)	13,393 (9.32%)	12.41%

in-degrees have flat, long tails. However, in most cases, these tails formed from a number of central hubs that correspond to original posters of various discussion threads. Such hubs actually performed more like a platform than an individual participant. If we discount these hubs, the in-degree distribution also follows power-law distribution. The powers of in-degree and out-degree were –1.62 and –2.48, respectively, for the South China Tiger network, and –2.21 and –2.63, respectively, for the outrageously priced haircut network.

This means that a few participants generated most of the citations and a few participants got cited in these citations. We also found that out-degree dropped off much more rapidly than in-degree. Further, there were fewer nodes that cited many other nodes than the nodes that received citations from a large number of other nodes.

Comparing HFS network findings with those for blogs, we see that the in- and out-degree distributions of the posting-level blogsphere vary significantly among different blog servers. In an analysis with IBM's internal blogs between November 2003 and August 2006,[2] the in-degree distribution followed power-law with a power of –1.6, comparable to the South China Tiger network, but smaller than the outrageously priced haircut network. The out-degree distribution followed power-law with a power of –1.9, which is much lower than both HFS networks.

Another empirical analysis based on data from different blog sites revealed that for blog networks, the in- and out-degree distributions both followed a heavy-tailed distribution, with a shallow power-law exponent of –1.7 for the in-degree distribution. The in- and out-degree distributions of the post network followed a power law (exponents –2.1 and –2.9 for in- and out-degree distributions).[3]

Other researchers also reported that the out-degree distribution for blog networks have slight deviations from power-law distribution, possibly because of data sampling limitations.[4] In our studies, most of the HFS networks' out-degree data fit the power-law distribution very well.

Small-world effect and connectivity

The average shortest path is 5.167 for the South China Tiger network and 4.331 for the outrageously priced haircut network, with a diameter of 12 for the South China Tiger network and nine for the outrageously priced haircut network. If we treat the networks as undirected, the average shortest paths for both are only 4.420 and 2.399, respectively; the diameters are 10 and 4, respectively. These numbers are very small compared to the total number of nodes in these networks—5,612 and 1,157, respectively. In addition, the clustering coefficients of the two networks are 0.057 and 0.079, many times larger than the theoretical predictions for random networks with the same size—0.00025 and 0.001, respectively. These observations indicate that the South China Tiger and outrageously priced haircut networks show the small-world effect, which has been observed in many kinds of networks, including the Web, the blogosphere, coauthorship networks, and many other social networks.[4–7]

However, possessing the small-world effect doesn't necessarily mean that information can diffuse easily. In both networks, only 1 percent of the node pairs in the network are reachable, many fewer than the 22.11 percent for blogs[4] and 25 percent for the Web.[8] This is because HFS networks are highly connected via central hubs and most nodes are casual nodes, only generating citations and replies to the central hub and otherwise contributing none.

Another measure used to determine network connectivity is the ratio between the maximum strongly connected components (SCCs) and the weakly connected components (WCCs) of the network. Table 4 shows our results. We found that the connectivity of HFS network samples is weaker than that of the Web and blogosphere. The fraction of the max WCC in the South China Tiger network reached 100 percent, a result of parallel searches across different HFS engines. The outrageously priced haircut network, on the other hand, split into two parts.

Evolutionary patterns

We conducted several studies to examine the evolutionary patterns of HFS participant networks and discovered the following: as previously noted, both the South China Tiger network and the outrageously priced haircut network had a large max WCC but a relatively small max SCC. We further observe that for the South China Tiger network, through slicing the entire duration of the episode into 10-day periods and comparing observations over these periods, both the size of the max SCC and max WCC—the network itself—grew larger, while the connectivity increased with network growth. We also observed that

while the fraction of WCCs (100 percent) didn't change, the size of WCCs continued to grow with the number of nodes; the max SCCs' growth slowed after reaching a certain size. This indicates that the clustering coefficient decreased with time, which is the opposite of the blogosphere, while the fraction of reachable node pairs increased with time.

Jure Leskovec and colleagues described the densification law prevalent in many networks,[9] which is also the case for the South China Tiger and outrageously priced haircut networks: the number of edges grew superlinearly to the number of nodes over time, with the densification exponent $\alpha = 1.21$ for the South China Tiger network and $\alpha = 1.07$ for the outrageously priced haircut network, comparable to the value for the graph of routers in the Internet (1.18), smaller than the values for the patent network (1.66)[9] and the blogosphere (1.928).[4]

Human flesh research is an important area for cross-disciplinary research, in part because it is a significant Web application drawing worldwide attention and because it has a strong and unique cultural root. From a technical research perspective, HFS shares many common characteristics with emerging social search engines, yet encourages a much broader range of online and offline interactions.[10]

HFS provides a fruitful dataset that can be used to develop and test new social networks and complex network theories and models, while also conducting research into network-centric machine learning and data mining.[11]

We envision that the unique online/offline interactions abundant in HFS episodes could provide critically needed insights facilitating the development of new social theory that blends traditional social theory, which focuses mostly on offline behavior, with newer studies focusing on online behavior.[11,12] HFS communities can be viewed as a special kind of cyber-enabled social movement organization. The uniquely massive online/offline interactions of HFS will open new venues for conducting high-impact, data-driven research to empirically test various theories and hypotheses that, until now, have been impossible or prohibitively expensive to test.

Acknowledgments

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